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Zoological Research

A Comparison of Macrofauna Communities in Different Mangrove Assemblages

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Abstract: The characteristics of macrofauna communities in three mangrove assemblages [*Avicennia marina* + *Acgiceras corniculatum* (MC) community, *A. corniculatum* (C) community and *Bruguiera gymnorrhiza* + *A. corniculatum* (GC) community] were studied in Zhanjiang Mangrove Nature Reserves during 2005 and 2006. Of the three mangrove assemblages, the macrofauna species number, density, biomass, Richness index and Shannon-Wiener index were the highest, and the Simpson dominance index was medial at MC community. However the Pielou Evenness index of MC community was slightly lower than that at C community. At C community, the number of macrofauna species obviously reduced, especially infaunal, caving and adhering life forms, and the biomass and density were the lowest. Because of the even distribution of individuals of different species, the Simpson dominance index was the lowest and the evenness index was the highest. Although the Richness index at C community was slightly lower than that at MC community, the Shannon-Wiener index was near to that at MC community. At GC community, the number of macrofauna species, especially infaunal and caving life forms, continued to decrease comparing C community, but the biomass and density increased slightly. As the distribution of individuals of different species was uneven, the Simpson dominance index was the highest and the Pielou Evenness index was the lowest. Furthermore, the Richness index dropped to the lowest. The Shannon-Wiener index also dropped accordingly to the lowest. The dominant life forms of MC were infaunal and caving, while those of C and GC community were both caving. The ratio of the GS/GSB of macrofauna communities in the three mangrove assemblages were 0.48, 0.63 and 0.80, respectively. The community structures at the same mangrove assemblages were all quite similar, with those at GC community being most similar. However, there were obvious differences among the community structures at the three different mangrove assemblages. These results implied that the different mangrove assemblages had different affects on the macrofauna communities and shed light on the macrofauna adaptation capability to specific habitats.

Key words: Mangrove community; Macrofauna; Community structure

不同红树植物群落中大型底栖动物群落的比较

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摘要: 2005—2006 年对广东湛江红树林国家级自然保护区湿地三种红树植物群落(白骨壤 + 桐化树群落、桐花树群落、木榄 + 桐花树群落)的大型底栖动物群落特征进行了分析研究。白骨壤 + 桐化树群落大型底栖动物群落的物种数、栖息密度、生物量、丰富度指数和多样性指数均最高, 优势度指数居中, 均匀度指数略低于桐花树群落; 桐花树群落大型底栖动物物种数急剧减少, 尤其是底内型、底上附着型和穴居型种类减少明显, 生物量和栖息密度下降到最低, 由于个体数种间分配较为均匀而导致优势度指数下降而均匀度指数增高, 虽丰富度指数略低于白骨壤 + 桐化树群落, 但多样性指数接近于白骨壤 + 桐化群落; 木榄 + 桐花树群落, 大型底栖动物群落的物种数, 尤其是穴居型和底内型种数继续减少, 但生物量和栖息密度有所上升, 个体数种间分配不

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均匀而使优势度指数增高而均匀度下降，加上丰富度指数最低，故多样性指数最小。白骨壤+桐花树群落优势种的生活型是底内型和穴居型；桐花树和木榄+桐花树群落优势种的生活型均是穴居型。三种红树植物群落中的大型底栖动物群落的 GS/GSB 分别为 0.48、0.63、0.80。相同红树植物群落大型底栖动物群落结构都较为相似，木榄+桐花树群落的相似性最高，而不同红树植物群落大型底栖动物群落特征的差异明显，反映了不同红树群落对底栖动物群落作用的差别，同时也展示了各种大型底栖动物对不同红树群落生境的适应情况。

关键词：红树植物群落；大型底栖动物；群落结构
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Mangrove vegetation plays an important role in maintaining environmental complexity and influencing the diversity and distribution of animals related to the ecological system (Lee, 1998; Roach & Lim, 2000; Liu et al, 2006; Gao et al, 2005). Destruction of mangrove areas reduces the diversity of macrofauna communities (Fondo & Martens, 1998). However at the same time, macrofauna plays an important part in mangrove ecological systems; they are both the consumer and transporter in the energy flow and materials circulation of the system. Through activities such as ingesting food and digging caves, macrofauna interact with their surrounding environment. Therefore their community structure is a significant biological index to measure a mangrove association's environmental characteristics and to predict mangrove environmental quality. Furthermore, macrofauna community structure is the potential biological or ecological index to recognize environmental changes in both natural and artificial mangroves.

The macrofauna of mangroves has been studied extensively, mainly in aspects of the species composition, density, biomass and diversity (Zou et al, 1999; Lin et al, 2006; Zhu & Lu, 2003; Yuan & Lu, 2001). However there has been quite limited discussion on the characteristics of macrofauna communities within different mangrove communities or associations (Chen et al, 2006). In the surveys of the mangroves in the Mipu Nature Reserve, Hong Kong (Lee & Kwok, 2002), both the species and quantity of two Sesarma communities, which were living quite closely in *Kandelia candel* and *Avicennia marina* mangrove communities respectively, were found to be distinctly different.

Three mangrove associations (*Avicennia marina* + *Acgiceras corniculatum*, *Acgiceras corniculatum* and *Bruguiera gymnorrhiza* + *Acgiceras corniculatum*) were chosen to investigate the macrofauna community structure in the Zhanjiang Mangrove Nature Reserve, Guangdong, China. The results can serve to highlight the influences of different mangrove vegetation on macrofauna community structure. Moreover, they may provide fundamental materials for the research on both the structural reconstruction and functional recovery of mangrove wetland ecological systems.

1 Materials and Methods

1.1 Research region overview

The Zhanjiang Mangrove Nature Reserve is one of 21 important international wetlands, located at 21°30′N, 109°41′E, within Yingluo Bay of the North Gulf, in the extreme west of Guangdong Province. It is located at the transitional region of the North and South Subtropical Zones. The yearly average temperature is 22.4℃, with a maximum of 37.4℃ and a minimum of −0.8℃. The yearly average rainfall is 1 816 mm, which falls mainly from May to September. Furthermore, the yearly average humidity is 81.8%. The tide is the mixing diurnal type, with 2.53 m of mean tide range and 6.25 m of extreme tide range, and the depth of water in the mangroves can increase by up to 2.5 m at the highest tide. The total area of the Mangrove Nature Reserve is 2 470 ha, containing 1 250 ha of forest area. The length of bank is 27 km and the average width of the tree belt is 500 m. Moreover, the mangrove area is at the junction of the Ximi, Jiangbei, Gaoqiao and Maichuo Rivers. Thus, the soil type is mainly sedimentary argillaceous beach swamp.

1.2 Method of sampling and sample treatment

Four classic *Avicennia marina* + *Acgiceras corniculatum* communities in the core region of the Zhangjiang Mangrove Nature Reserve (located along the coastal areas of the Leizhou Peninsula, Guangdong, China) were selected as study sites, ranging from coastal to offshore and four investigation stations (A1-A4) were established at the sites during 2005 to 2006. In addition, near the tidal line of each station, *Acgiceras corniculatum* communities and *Bruguiera gymnorrhiza* + *Acgiceras corniculatum* communities were also selected and further investigation stations were set up accordingly (B1-B4 and C1-C4, respectively). Macrofauna was investigated at each investiga-

tion station using four quantitative sample frames (25 cm × 25 cm). Epifauna were removed and sediment was subsequently dug up to a depth of 30 cm. Infauna were sampled using a 0.5 mm sieve. Collected samples were immediately fixed in 5% formalin and subsequently analyzed in the laboratory. Sampling plots (10 m × 5 m) were established at each investigation station. All plants within the sampling plots were investigated completely, and measurements were taken of: tree height; tree crown (NS × EW); diameter at breast height; and base cover of mangrove. In each sampling plot, the sediment from 0 – 30 cm depth was removed and mixed using diagonal sampling. The mixed sediment, weighing approximately one kilogram, was used as the test sample. The grain size distribution, content of salt and organic matter composition of the soil were determined using a hydrometer, gravimetric analysis and the potassium dichromate method, respectively. Measurements of pH were also taken by potential method. Tests on each sample were repeated three times.

1.3 Groups and life forms of macrofauna

Macrofauna groups can be divided into (two groups): (1) surface group (GS), including all life forms living on the substrate, covering adhering species (all species of Gastropoda and *Ostrea mordax*), crawling species (the Isopoda species) and swimming species (several shrimps of Crustacea and *Periophthalmus cantonensis* of Osteichthyes); (2) below surface group (GSB), including all life forms living beneath the substrate, covering infaunal species (all species of Bivalvia、Polychaeta and *Phascolosoma* sp., *P. esculenta* of Phascolosomatidae) and cave-dwelling species (the crabs of Crustacea) (Day et al, 1989; Yang et al, 1996; Fan et al, 2000). Based on the collected samples, the macrofauna were divided into four kinds of life forms (adhering, swimming, infaunal and cave-dwelling), as the Isopoda species were not collected at the time of sampling. Results for GS and GSB are expressed as the number of species. GS/GSB values are used to express the effect of environment at different mangrove communities upon the number of species of the two groups.

1.4 Statistical analysis of macrofauna communities

1.4.1 Determination of the diversity The macrofauna data from the four quantitative sample frames at each investigation station were combined and the Margalef Richness index (d), Shannon-Wiener index (H'), Pielou Evenness index (J') and Simpson dominance index (C) were used to describe the diversity of the macrofauna community, according to the following equations.

The Margalef Richness index:

$$d = (S - 1)/\log_2 N \tag{1}$$

The Shannon-Wiener index:

$$H' = -\sum_{i=1}^{S} (P_i)(\ln P_i) \tag{2}$$

The Pielou Evenness index:

$$J' = H'/H'_{\max}; \quad H'_{\max} = \ln S \tag{3}$$

The Simpson dominance index:

$$C = \sum_{i=1}^{S} (P_i)^2 \tag{4}$$

where S represents the total number of species; N is the total number of individuals; and P_i is the ratio of number of individuals of i species to the total number of individuals in the sample.

1.4.2 Significant differential analysis The statistical software package SPSS12.0 was used to analyze the data. T-tests and one-way ANOVA were used to compare data.

1.4.3 Relativity analysis All relativity analysis was carried out using the statistical software package SPSS12.0 (Pearson Correlation).

1.4.4 Cluster and ordering analysis of macrofauna community The twelve stations were grouped into clusters using classification and MDS ordination techniques. These are both based on fourth root transformed abundance data with Bray-Curtis measures of similarity. The multivariate statistical software PRIMER (Plymouth Routines in Multivariate Ecological Research) 5.0 was used for CLUSTER and MDS analysis.

2 Results and Analysis

2.1 Characteristics of mangrove communities and sediments

Analysis of data from each station showed that tree height, tree crown (NS), tree crown (EW) and base cover showed distinct gradient differences (Tab. 1). If the data from each station were combined according to the mangrove community type, the change of trend for values of all characteristics of the three mangrove communities was MC < C < GC (Fig. 1). Results also showed that the pH value, average content of organic matter, salt, sand, silt, and clay had distinct gradient differences (Tab. 2). From MC to C, then to GC communities, the average content of organic matter, salt,

silt, and clay increased, while the pH value and sand content decreased (Fig. 1).

2.2 Species and composition of macrofauna life forms

Fifty-six macrofauna species were recorded at the three mangrove communities, belonging to five phyla, six classes and 27 families (Tab. 3). The number of species of Crustacea, Mollusca, Polychaeta and others were 27, 20, 6 and 3 (accounting for 48.21%, 35.71%, 10.71% and 5.37% of the total number of species), respectively.

The overall species composition of macrofauna is given in Fig. 2. There were 46 macrofauna species at the MC community, with most species belonging to Crustacea and Mollusca, ($n = 21$ and $n = 18$ respectively, accounting for 45.65% and 39.13% of the total number of species at this mangrove community). In addition, there were five species of Polychaeta in this mangrove type, which was the highest number of polychaetes in the three mangrove communities. There were 31 macrofauna species at the C community, dominated by Crustacea ($n = 17$) which accounted for 54.84% of the total number of species within this mangrove community. There were three of other at C community, which was the highest of all three mangrove communities. Finally, there were 27 species at the GC community. Crustacea was again dominant ($n = 14$), accounting for 51.85% of the total number of species. There was one species of other category at this community, which was the lowest of the three mangrove communities.

The number of species of each life form and life group at each mangrove community are listed in Tab. 4. The species number was the highest at the MC community and the dominant macrofauna life forms were mainly caving and infaunal. For community C, the dominant life form was caving, and the number of caving, infaunal and adhering species decreased sharply from MC to C (especially that of infaunal from 14 to 6 species). For the GC community, the dominant life form was caving, but the number of both caving and infaunal life forms continued to decrease from C to GC (from 13 to 10 and 6 to 5, respectively). The GS/GSB at the three mangrove communities was 0.48, 0.63 and 0.80, respectively. These results indicate that great differences exist among the life form groups of macrofauna communities at the MC, C and CG communities.

Tab. 1 Mangrove community characteristics at each sampling plot

Sampling plot	Community type	Tree height (m)	Tree crown North × South (m)	Tree crown West × East (m)	Base cover (%)
A1	*Avicennia marina + Acgiceras corniculatum*	1.62	1.04	1.01	0.34
A2	*Avicennia marina + Acgiceras corniculatum*	1.14	1.19	1.12	0.15
A3	*Avicennia marina + Acgiceras corniculatum*	1.57	1.11	1.03	0.55
A4	*Avicennia marina + Acgiceras corniculatum*	1.83	1.32	1.31	0.36
B1	*Acgiceras corniculatum*	2.01	1.33	1.34	0.60
B2	*Acgiceras corniculatum*	2.25	1.51	1.25	0.75
B3	*Acgiceras corniculatum*	2.02	1.05	1.21	0.61
B4	*Acgiceras corniculatum*	2.05	1.79	1.69	0.64
C1	*Bruguiera gymnorrhiza + Acgiceras corniculatum*	2.53	2.03	1.96	0.76
C2	*Bruguiera gymnorrhiza + Acgiceras corniculatum*	2.63	2.18	2.10	1.09
C3	*Bruguiera gymnorrhiza + Acgiceras corniculatum*	2.81	2.01	1.85	0.79
C4	*Bruguiera gymnorrhiza + Acgiceras corniculatum*	2.40	1.75	1.75	0.71

Tab. 2 Sediment characteristics at each sampling plot

Sampling plot	pH	Organic matter (g/kg)	Salt (g/kg)	Sand (%)	Silt (%)	Clay (%)
A1	6.69	34.48	18.81	60.10	31.10	8.80
A2	6.53	35.52	19.66	60.90	30.85	8.25
A3	6.50	36.98	19.76	64.70	27.60	7.70
A4	6.77	31.53	20.25	65.38	26.68	7.94
B1	6.55	31.85	20.75	59.60	32.10	8.30
B2	6.50	37.28	20.83	58.32	33.01	8.67
B3	6.45	39.25	20.73	56.90	35.30	7.80
B4	6.46	38.70	20.18	57.60	34.10	8.30
C1	6.04	89.70	21.91	50.90	40.80	8.30
C2	6.05	69.45	20.87	52.31	39.10	8.59
C3	6.05	59.15	21.71	53.71	37.17	9.12
C4	6.30	64.38	20.82	53.06	35.79	11.15

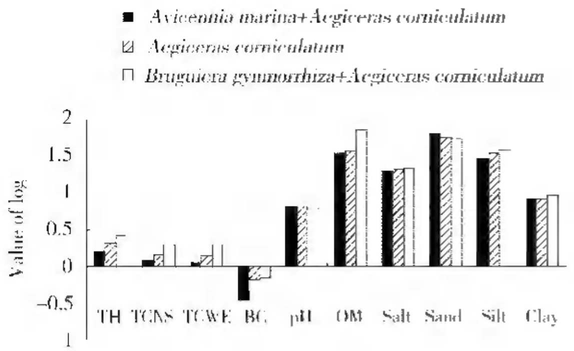

Fig. 1 Changing trends of mangrove community and sediment characteristics of the three mangrove communities
TH: Tree height; TCNS: Tree crown (North × South); TCWE: Tree crown (West × East); BC: Base cover; OM: Organic matter.

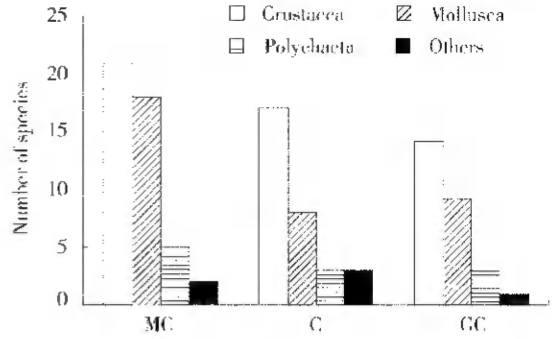

Fig. 2 The species composition of macrofauna at three mangrove communities

Tab. 3 Species, life forms and distribution of macrofauna at the three mangrove communities

Species	Mangrove communities MC	C	GC	Life form IN	CA	AD	SW
Ceratonereis burmensis	++	++	++	*			
Perinereis cultrifera	++			*			
Glycera chirori	+		++	*			
Lumbrineris heteropoda	+	+	+	*			
Traoisia sp.		+		*			
Phascolosoma sp.		+		*			
P. esculenta	++	++		*			
Modiolus philippinarum	++			*			
Moerella iridescens	+			*			
Pharella acutidens	+			*			
Polymesoda erosa	++		+	*			
Meretrix meretrix	+	++	++	*			
Clausinella isabellina	+			*			
Laternula truncata	+			*			
Ostrea mordax	+					*	
Pseudoringicula sinensis	++	++	++			*	
Littoraria melanostoma	++	+++	+			*	
L. scaber	++	+				*	
Assiminea lutea	+++	++	+++			*	
Cerithidae cingulata	++		+			*	
C. ornata	+	++	+			*	
Cerithum sinense		+				*	
Nassarius hepaticus	+					*	
N. siquijorensis	+					*	
Ellobium aurismidae	+		+			*	
A Species of Ellobiidae		++	++			*	
Metapenaeus affinis	+	+	++				*
Parapenaeopsis hardwickii	+	++	++				*
Macrobrachium nipponensis		+	+				*
M. gracilirostre	+						*
Upogebia sp.	+	+++	++				*
Periophthalmus cantonensis	+	++	+				*
Ommatocarcinus macgillivrayi	+		+		*		
Uca arcuata	++	++	+		*		
U. vocans borealis	+				*		
U. triangularis triangularis	++	++	+		*		
Macrophthalmus erato	++	+			*		
M. latreillei		+			*		
M. pacificus	++		+		*		
M. definitus	++				*		
Cleistostoma dilatatum	++	++	+++		*		
Paracleistostoma depressum	+++	+++	+++		*		
P. crassipilum	+		+		*		
Ilyoplax dentimerosa		++			*		
Il. serrata	+				*		
Il. tansuiensis		++			*		
Nanosesarma pontianacensis	+				*		
Sesarma bidens	+	+	++		*		
S. plicata	+	++	++		*		
S. haematocheir		+			*		
S. sinensis	+				*		
Cyclograpsus incisus		++			*		
Metaplax longipes	+	+	+		*		
Percnon sinense	+				*		
Total	46	31	27				

MC, C and GC stand for *Avicennia marina + Acgiceras corniculatum* community, *Acgiceras corniculatum* community and *Bruguiera gymnorrhiza + Acgiceras corniculatum* community respectively.
+ : individual number < 1% of the total; ++ : between 1%–10% of the total; +++ : > 10% of the total; IN, CA, AD, SW stand for the life forms of infaunal, caving, adhering and swimming respectively. * stands for the record of the life form. The same below.

2.3 Density and biomass of macrofauna communities

The density and biomass of macrofauna communities at the three mangrove communities showed the following trend: MC > GC > C (Tab. 4). Density was significantly different among the three mangrove communities (One-way ANOVA, $P < 0.05$), However the difference in biomass (wet weight) was not significant (One-way ANOVA, $P > 0.05$).

2.4 Species diversity of macrofauna communities

Although the Pielou Evenness index of the MC community was slightly lower and the Simpson domi-

nance index was slightly higher than those of community C, the Shannon-Wiener diversity index was higher due to the Margalef Richness index being the highest at MC community of all three mangrove communities (Tab. 4). Within the C community, the Margalef Richness index was medial, but the Simpson dominance index was the lowest, and the Pielou Evenness index was highest, of all mangrove communities. This was due to the distribution of individuals of different macrofauna species being more even, causing the Shannon-Wiener diversity index to be close to that of community MC. At the GC community, although the Pielou Evenness index was the same as that of the MC community, the Margalef Richness index was the lowest of the three mangrove communities. The Simpson dominance index was the highest of all mangrove communities because the interspecies distribution of individuals was more centralized than that of the other two communities. At GC, the dominant species such as *Paracleistostoma depressum*, *Assiminea lutea* and *Cleistostoma dilatatum*, accounted for 28.50%, 27.63% and 10.54% of the total number of species respectively, causing the Shannon-Wiener diversity index to be the lowest of the three mangrove communities. Correlation analysis indicated that the Shannon-Wiener diversity index of all mangrove communities was negatively correlated with the Simpson dominance index ($r = -0.855$, $P < 0.01$), and positively correlated with the Pielou Evenness index and the Margalef Richness index ($r = 0.633$, $P < 0.05$; $r = 0.729$, $P < 0.01$).

2.5 Cluster and ordering of macrofauna communities

The twelve investigation stations were divided into three groups: A1, A2, A3, A4; B1, B2, B3, B4; C1, C2, C3, C4; corresponding to the MC, C and GC communities, respectively. Cluster analysis (Fig. 3) showed that the macrofauna communities at each of the mangrove communities were distinguishably different, and those at C and GC community were relatively most similar.

Tab. 4 Macrofauna community characteristics at the three mangrove types

Items		MC	C	GC
Number of species of each life form	Swimming	5	5	5
	Adhering	10	7	7
	Infaunal	14	6	5
	Caving	17	13	10
Number of species of each life group	GS	15	12	12
	GSB	31	19	15
	GS/GSB	0.48	0.63	0.8
Density (ind./m^2)		232.00 ± 53.19	78.75 ± 15.97	144.75 ± 20.38
Biomass (g/m^2)		81.36 ± 59.93	46.47 ± 22.77	63.03 ± 45.76
Diversity indices	H'	2.36	2.35	2.06
	J'	0.74	0.83	0.74
	d	2.94	2.55	2.18
	C	0.16	0.14	0.19

GS: Surface group; GSB: Below surface group; H': Shannon-Wiener index; J': Evenness index; d: Richness index; C: Simpson's dominance index

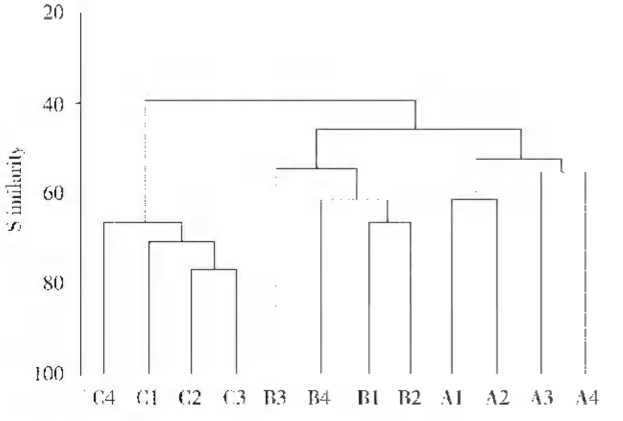

Fig. 3 The hierarchical cluster dendrogram of macrofauna communities at different sampling plots

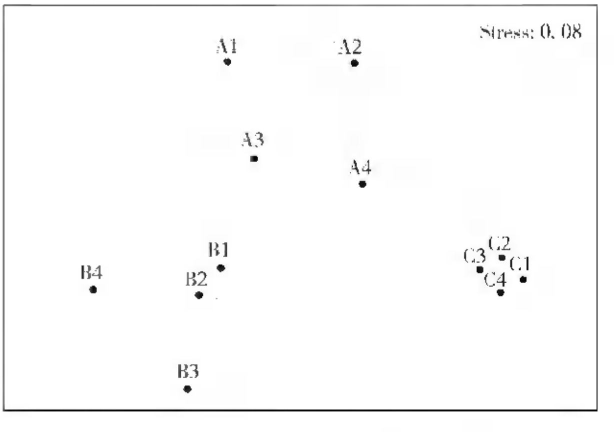

Fig. 4 MDS ordination of macrofauna communities at different sampling plots

Tab. 5 The correlation between environmental and community characteristics at each sampling plot

	Tree height	Tree crown North × South	Tree crown West × East	Base cover	pH	Organic matter	Salt	Sand	Silt	Clay
Swimming	0.580*	NS	NS	NS	NS	NS	NS	NS	NS	NS
Adhering	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Infaunal	−0.699*	NS	−0.596*	−0.666*	0.673*	NS	−0.638*	0.820**	−0.844**	NS
Caving	−0.908**	−0.719**	−0.776**	−0.662*	0.627*	−0.639*	−0.824**	0.762**	−0.756**	NS
GS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
GSB	−0.849**	−0.681*	−0.725**	−0.715**	0.703*	−0.579*	−0.773**	0.855**	−0.867**	NS
S	−0.799**	NS	−0.594*	−0.785**	0.676*	NS	−0.683*	0.807**	−0.833**	NS
Density	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Biomass	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
H'	−0.762**	−0.720**	−0.682*	−0.676*	0.748**	−0.800**	−0.594*	0.635*	−0.628*	NS
J'	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
d	−0.831**	−0.695*	−0.709**	−0.759**	0.757**	−0.721**	−0.641*	0.827**	−0.862**	NS
C	NS	0.588*	NS	NS	NS	NS	NS	NS	NS	NS

GS: Surface group; GSB: Below surface group; *S*: Number of species; *H'*: Shannon-Wiener index; *J'*: Evenness index; *d*: Richness index; *C*: Simpson's Dominance index. * $P < 0.05$; ** $P < 0.01$; NS: $P > 0.05$.

Ordering analysis showed that macrofauna communities of the same mangrove community were divided into the same groups (Fig. 4). The stress value (0.08 < 0.1) indicated that the result is credible (Clarke & Gorbey, 2001; Yang et al, 2006). The sampling stations at the C and GC communities, which were very similar in the results of the cluster analysis, were clearly separated. This indicates that the macrofauna communities at the two sites were still different. In comparison, the distance among the four sampling stations representing the GC community were the shortest, implying that the structure of macrofauna communities at this community was most similar (Fig. 4).

2.6 The relationship of macrofauna communities with mangrove communities and environmental factors

The relationship between the number of species of each life form, biomass, density, diversity of macrofauna communities, sediments and the characteristics of each mangrove community are listed in Tab. 5.

3 Discussion

This study shows that the macrofauna communities of three different mangrove associations have obvious variations. Moreover, cluster analyses and MDS ordination showed that the structures of macrofauna communities at different mangrove communities can be distinguished from each other. At the MC (*Avicennia marina* + *Acgiceras corniculatum*) community, the number of species, biomass, density, Richness index, and Shannon-Wiener index of macrofauna communities were the highest, and the Simpson dominance index was at the midpoint of those of all three mangrove communities. The Pielou Evenness index was slightly lower than that at community C (*Acgiceras corniculatum*). In community C, the number of species of the macrofauna communities, especially infaunal, adhering and caving life forms, significantly reduced, and the biomass and the density were the lowest of all three mangrove communities. Because of the even distribution of individuals of different species within community C, the dominance index decreased and the evenness index increased. As a result, the diversity index was very close to that of the MC community although the Richness index was slightly lower. At the GC community, the number of macrofauna species continued to decrease, especially among the infaunal and caving life forms. However the density and biomass increased slightly. Due to the uneven distribution of individuals of different species, the dominance index increased and the evenness index decreased. As a result, the diversity index was the lowest and the Richness index was the lowest of all mangrove community types surveyed.

The structure of the macrofauna communities were obviously different from each other at different mangrove associations, which were related to the fact that their immediate habitat is provided by mangrove vegetation. Firstly, the chemical properties of sediments at different mangrove communities are sharply different from each other, and are affected by community type, especially by the growth rate of the dominant species, the thickness of plant litters and the nutrition content of the mangrove community (He et al, 2001). It is well known that the chemical properties of sediments affect macrofauna communities (Wang et al, 2002; Yuan et al, 2002; Li et al, 2003).

Secondly, the diversity of macrofauna communities can be influenced by the light intensity of mangroves. Research on natural mangroves in Australia showed that the species and distribution of crabs can be greatly influenced by the presence or absence of mangrove vegetation, which results from the difference in shade conditions (Nobbs, 2003). Moreover, Vannini et al (1995) showed that the light level of natural mangroves had significant impact on the distribution of Sesarma species. Highly significant positive correlation exists between the density of *Avicennia alba* and *Ovassiminea brevicula* offspring in Thailand, which were the main macrofauna species in mangroves in the study area (Suzuki et al, 2002). Furthermore, mangroves can provide food for macrofauna directly or indirectly (Capehart & Hackney, 1989; Stoner, 1980). Different macrofauna feed on the broken branches and fallen leaves of different mangrove species and show foraging "selectivity". Thus, the distinction of physical characteristics among different mangrove community types could directly lead to the difference in macrofauna subsystems. The major consumers of mangrove vegetable materials, such as fallen leaves, in previous studies have been crabs (Robertson & Daniel, 1989; Micheli, 1993; Steinke et al, 1993; Schories et al, 2003) and gastropods (Slim et al, 1997). Recent research showed that some species could be quite selective while eating mangrove fallen leaves (Ashton, 2002; Erickson et al, 2003; Fratini et al, 2001). However, the consumption of mangrove fallen leaves by crabs was determined, to different degrees, by both plant species and leaf blade condition (fresh or overgrown). This was demonstrated by chewing tests in which two types of Sesarmas (*Sesarma eumolpe* and *S. onychophorum*) were fed with fresh and fallen leaves of four mangrove species (*Avicennia officinalis*, *Bruguiera gymnorrhiza*, *Bruguiera parviflora* and *Rhizophora apiculata*) (Ashton, 2002). Similarly *Aratus pisonni* was shown to have a preference for the three mangrove species (*Rhizophora mangle*, *Avicennia germinans* and *Laguncularia racemosa*) (Erickson et al, 2003). Gastropods sense different incomplete mangrove leaves by olfactory perception (Fratini et al, 2001). Thus, leaves of different types and conditions can be selected by gastropod because of the distinction of their smell.

Finally, both the abundance and diversity of macrofauna communities can be greatly influenced by variations in surface topography and by micro-geomorphy elements of tidal mangrove beaches. Different mangrove communities can themselves cause variations in tide beach surface geomorphy. These changes, combined with the complexity of plant structures, not only create colonization sites but also provide shelter for macrofauna species avoiding predation (Lin, 1997). In this study, predators such as *Periophthalmus cantonensis* were found to feed on other macrofauna at the three mangrove communities. These elements are also likely to have induced differences in macrofauna communities.

Of the three mangrove communities, the content of sand at the MC community was the highest ($P < 0.01$) and that of silt was the lowest ($P < 0.01$). As a result, the substrate was loose and easily drilled. Furthermore, the content of salt and organic matter were both the lowest of all the sites ($P < 0.01$). Compared with the other two communities, the pH value was higher ($P < 0.01$) and acidity of sediments was lower, which created suitable habitat for infaunal and caving life forms (Liu et al, 2006). As a result, the number of species of these life forms was the highest at this mangrove community type. Following from this, the number of GSB species was also highest of the three communities.

The tree height, tree crown (NS and EW) showed significant or highly significant positive correlation with the contents of organic matter and silt ($P < 0.05$ or $P < 0.01$), but had significant or highly significant negative correlation with pH value, the content of salt and sand ($P < 0.05$ or $P < 0.01$). This indicates that the chemical property of sediments would not only directly affect the macrofauna community structure, but also the development of mangrove (growth of tree height and enlargement of tree crown). Furthermore, the mangrove base cover was the main influence on the shadow status and light intensity in mangroves, which also influences the diversity of macrofauna communities (Gao et al, 2005). The data in Tab. 5 show that tree height, tree crown and base cover all had significant or highly significant negative correlations with the number of infaunal and caving species and the number of GSB ($P < 0.05$ or $P < 0.01$). Tree height, tree crown and base cover at MC community were the least of the three mangrove communities ($P < 0.01$ or $P < 0.05$), leading to a high number of infaunal and caving species, and a higher abundance of GSB species than those at the other two mangrove communities. All these factors led to the number of species, Richness index and den-

sity at MC community being the highest of the three mangrove communities. Therefore the Shannon-Wiener diversity index was higher than that of community C although the Pielou Evenness index was lower and the Simpson dominance index higher because of the distribution of individuals of different species was less even than that of community C. Although the number of GS species at community MC was slightly higher than those of the other two communities, the ratio of GS/GSB was the least of the three communities. This is because the number of GSB species was far higher than those at the other two communities. Furthermore, Mollusca, whose life forms were infaunal (e.g. *Meretrix* and *Moerella iridescens*) at this community, were usually large, contributing to the highest biomass at MC community.

Compared with community MC, the content of sand of community C was lower ($P < 0.01$), the soil was looser, the pH value was lower ($P < 0.05$) and the acidity was stronger, which were not suitable for habitat characteristics for infaunal and caving life forms. Thus, the number of infaunal and caving species decreased rapidly, reducing the number of GSB species also. Nevertheless, there was a thick silt layer at community C, so the sediment surface was easily turned into mud by seawater flushing. This situation was unfavorable for adhering species to adhere and feed whose unit volume is large (e.g. *Cerithidea cingulatus* and *Cerithidea ornata*), causing the number of adhering species decrease sharply from MC community. Therefore the number of GS species also decreased. Because of the even distribution of individuals of different species, the Simpson dominance index was low, and the Pielou Evenness index was higher. As a result, the Shannon-Wiener diversity index was close to that of community MC, although the Richness index was slightly lower. The Pielou Evenness index was the highest of the three mangrove communities, but the density and the Simpson dominance index were the lowest. Although the number of GS species within community C was slightly lower than that of community MC, the ratio of GS/GSB species was higher than that of MC because the number of GSB species was far lower.

At the GC community, the content of sand in the sediment was the lowest of all mangrove communities ($P < 0.01$), and those of silt, salt and organic matter were all highest ($P < 0.01$). The acidity of the sediment was strong and the gas permeability was bad, leading to smelly air. The soil texture was half-hardened silt and was hard for drilling (Lin, 1997; Miao, 2000), which was not suitable for infaunal and caving life forms (Zou et al, 1999). Therefore the number of species of this type was the lowest of all mangrove communities, as was the number of GSB species. Furthermore, tree height, tree crown and base cover were the highest of the three mangrove communities ($P < 0.01$ or $P < 0.05$), which also contributed to the low number of infaunal, caving and GSB species. All these factors contributed to the lowest number of species and the lowest Richness index for any of the mangrove communities at GC. Because of the less even distribution of individuals of different species compared with the community C, the Pielou Evenness index decreased, but the Simpson dominance index rose slightly. As a result, the Shannon-Wiener diversity index was the lowest at GC. Although the number of GS species at GC was the same as that of C, the ratio of GS/GSB was higher. This was because the number of GSB species was far lower than that of community C.

Macrofauna community structures were obviously different from each other at the different mangrove communities sampled in this study, suggesting that mangrove structure and type can influence macrofauna community by direct or indirect environmental effects (change in chemical property of sediments and the light levels, provision of food and the surface geographies of the tide). Analysis of different life forms and groups of macrofauna within different mangrove communities can lend evidence to the function of mangroves, and at the same time show the adaptive abilities of various macrofauna to different habitat types. Therefore, in the restoration of mangrove wetland ecosystems which have been damaged by human interference, both the vegetation construction and its influence on macrofauna should be taken into consideration.

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